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AGRICULTURAL MEMORANDUM NO 385

The Effects of the Weather on the Yield of Maize in Britain(1)

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Grain yield data from plot trials at Wytham, near Oxford, of maize variety INRA 200 were available for the years 1958-1970 (except 1962 and 1963) along with weather records. This note is an attempt to relate the yield variation with the weather.

General Considerations

Figure 1 shows the variation of yield from year to year. Large fluctuations have occurred with 1965 and 1968 very poor, 1967 and 1969 quite good and the remaining years were nearer the average.

Table 1 lists the general character of the weather by months for good, average and poor yielding years. The weather elements are placed on a scale from 1 to 5, where the value 1 indicates that the weather element is much below average, the value 5 indicates it is much above average and the value 3 indicates it is about average. Maximum temperature was measured at the Radcliffe Observatory, Oxford, radiation refers to the mean of measurements at Cambridge, Kew and Bracknell of the total radiation on an horizontal surface, rainfall was measured at Radcliffe and potential transpiration was found by the simplified method (Ag Mem 374A).

The years with yield above or slightly above average were characterised by average to cool Mays with low radiation, above average rainfall and about average potential transpiration. Junes were mixed, but July and August were on the warm side with high radiation and rainfall average or above.

Poor yielding years generally had average Mays and Junes, cool weather in July and August and above average rain, with both radiation and potential transpiration on the low side.

Years which gave an average yield usually had very warm Mays with above average radiation and potential transpiration, but low rainfall. June was mixed, but July and August tended to be dry with temperature and radiation variable, sometimes distinctly above normal, but in other years only average.

Variation of Yield with Weather Elements

Maximum Temperature

Maximum temperature was thought to be a better measure of plant activity than mean temperature and figure 2 shows the yield plotted against the mean maximum temperature for each month May-September. Only July and August show an obvious correlation and even then the scatter is quite large. From the general considerations above, there ought to be some correlation between May temperatures and yield, but this is not apparent from the graph. Rainfall at this time may be more important than temperature.

Also in figure 2 the yield is plotted against the mean maximum temperature one month after flowering. For temperatures below 69°F there is a linear positive correlation, but above this temperature considerable scatter occurs.

FGS Stock 34

G. 13248/MD/6/71/70

Radiation

1. Pre-Conditioning Effects

Since maize seedlings emerge in late May and pass through the grain filling stage in August/September, the plants are subject to high radiation when young, but to progressively lower levels of radiation later. Daily radiation data were available for some years at Wytham and a tentative hypothesis can be made. During 1967 and 1969 (the high yielding years), radiation was low immediately after emergence (late May), high in early-mid June, but low again at the end of June. In fact the radiation level at the end of June was approximately equal to the level during grain filling in August. This may be significant since the leaves which grow at the end of June are those immediately next to the cob and presumably supply it with photosynthate. If these leaves grew in a high radiation environment they would not be so well adapted to the lower radiation conditions during grain filling.

2. Yield and Radiation

Figure 3 shows yield plotted against the mean of monthly mean total radiation measured at Cambridge, Kew and Bracknell, for May, June and September. Poor relationships are found apart from May when there is a negative association. The graphs for July and August are better. In an attempt to be more precise monthly mean radiation before and after flowering has been estimated from sunshine hours measured at Radcliffe. Little improvement was obtained.

Rainfall

Other investigations of cereal yield in NW Europe have shown that low yields tend to follow wet winters and vice versa. It has been suggested that this is related to leaching of nutrients in the soil. For the maize trials a plot of yield against November to March rainfall did not show any such relation. A plot of yield against July plus August rainfall showed a lot of scatter, but the general trend was for low yields when rainfall was either high or low (ie a parabolic curve). Figure 4 shows yield against May rainfall. Apart from the years 1968 and 1965 there is some positive correlation, which was indicated in the 'general considerations' above.

Irrigation experiments in dry Tropical countries have shown that Maize gives a large yield response to water applied at anthesis and during grain filling, particularly the former. Figure 5 shows the daily rainfall distribution around flowering time each year. It was particularly dry at flowering time in 1959, 1961, 1964 and 1965. All these years returned below average yields. The two high yielding years (1967, 1969) both had heavy showers on the flowering day. 1969 is especially interesting since in that year the trial plot which flowered on 30, 31st July (sunny, dry days) only had an average yield (52.0 cwt/acre), whereas those trial plots which flowered on 27, 28th July (rainy days) had higher yields (58.4, 59.6, 63.8 cwt/acre). Moreover in 1969, the rain fell after a long dry spell and there is some evidence which shows that uptake of nutrients is momentarily greater under these conditions than if rain falls frequently.

Other years do not fit this pattern quite so well. In particular 1970 had plenty of rain at flowering time, but only returned an average yield. This year also had a very dry early summer, which suggests the need to consider soil moisture deficit.

Yield and Soil Moisture Deficits

Potential transpiration for maize was found by the simplified procedure described in Ag. Mem. 374A. Soil moisture deficits (SMD) were calculated for the end of each month using rainfall data from Oxford. By itself SMD is a poor indication of yield and it was decided to combine SMD with the plots of yield against temperature and radiation.

The mean of the SMD's calculated for the end of July and August is plotted by each point on the graph of yield against maximum temperature one month after flowering (figure 2). There is a general tendency at any given temperature for the yield to increase as the SMD becomes less, (ie lower moisture stress) but the relation is different at different temperatures. When temperatures are low, SMD appears to have only a small effect, but for temperatures above about 69°F small changes in SMD seem to cause large yield variations. This broad picture is also the case when other parameters of plant water status are used (actual estimated transpiration and the ratio of actual to potential transpiration). For example the graph of yield against mean radiation for 1 month after flowering (figure 3) also has the ratio of actual to potential transpiration for August plotted by each point.

Conclusions

Three factors appear to affect the yield of maize: temperature, radiation and soil moisture. It is suggested that conditions at and after flowering time have the greatest effect on yield, even though some correlations between yield and pre-flowering weather do appear to exist. The correlation with July temperature may only imply that July and August temperatures are highly correlated, but "pre-conditioning" effects may be significant. The correlation with May rainfall may imply that plenty of water early in the growth cycle leads to a larger leaf area than in dry conditions. In turn the larger leaf area helps to increase photosynthesis after flowering.

The combination of cool and dull late summer weather is the worst yielding weather for maize. Temperature could be more important than radiation, since in the dull years considered the temperature and the yield varied more widely than radiation. Soil moisture conditions in this instance are probably not important since cool weather in August is usually wet as well.

At the opposite end of the scale, warm summers in Britain are usually dry, but the potentially high yields in these years are not achieved due to lack of soil water. If substantial rain falls at flowering time in an otherwise dry July/August then the data here suggests that some of this potential yield is realised. Since this coincidence of weather and crop stage is largely a matter of chance it will not be simple to draw up an expected yield map based on climate records.

An early preliminary yield estimate could be made at the end of May using rainfall.

Any comments or criticisms should be sent direct to the author.

Meteorological Office Met O 8a
Bracknell
Berkshire

June 1971

G. 13248/MD/6/71/70

Table 1. General weather characteristics May-August

Above average yield

	MAXIMUM TEMP				RADIATION				RAIN				POTENTIAL TRANSPIRATION			
YEAR	67	69	66	58	67	69	66	58	67	69	66	58	67	69	66	58
MAY	2	3	3	3	2	1	4	3	4	4	3	3	3	3	4	3
JUNE	3	3	4	3	3	4	3	1	3	2	4	5	4	5	3	2
JULY	4	5	3	3	5	4	3	3	4	2	4	3	4	4	3	3
AUGUST	3	4	3	3	4	3	4	2	2	4	4	3	3	3	3	2

Below average yield

	MAXIMUM TEMP		RADIATION		RAIN		POTENTIAL TRANSPIRATION	
YEAR	65	68	65	68	65	68	65	68
MAY	3	1	3	2	3	3	3	3
JUNE	3	3	3	2	3	4	3	3
JULY	1	2	1	2	4	5	2	2
AUGUST	3	2	3	1	3	4	3	1

Average yield

	MAXIMUM TEMP					RADIATION					RAIN					POTENTIAL TRANSPIRATION				
YEAR	59	60	61	64	70	59	60	61	64	70	59	60	61	64	70	59	60	61	64	70
MAY	5	4	3	5	5	4	3	4	4	4	2	3	2	3	2	4	3	4	3	3
JUNE	4	5	4	2	5	4	3	3	2	4	2	4	2	3	3	3	4	3	2	4
JULY	5	2	3	4	3	5	3	3	4	3	3	4	3	2	2	5	3	3	3	3
AUGUST	5	3	4	4	3	4	3	3	3	3	2	2	3	1	2	4	2	3	3	3

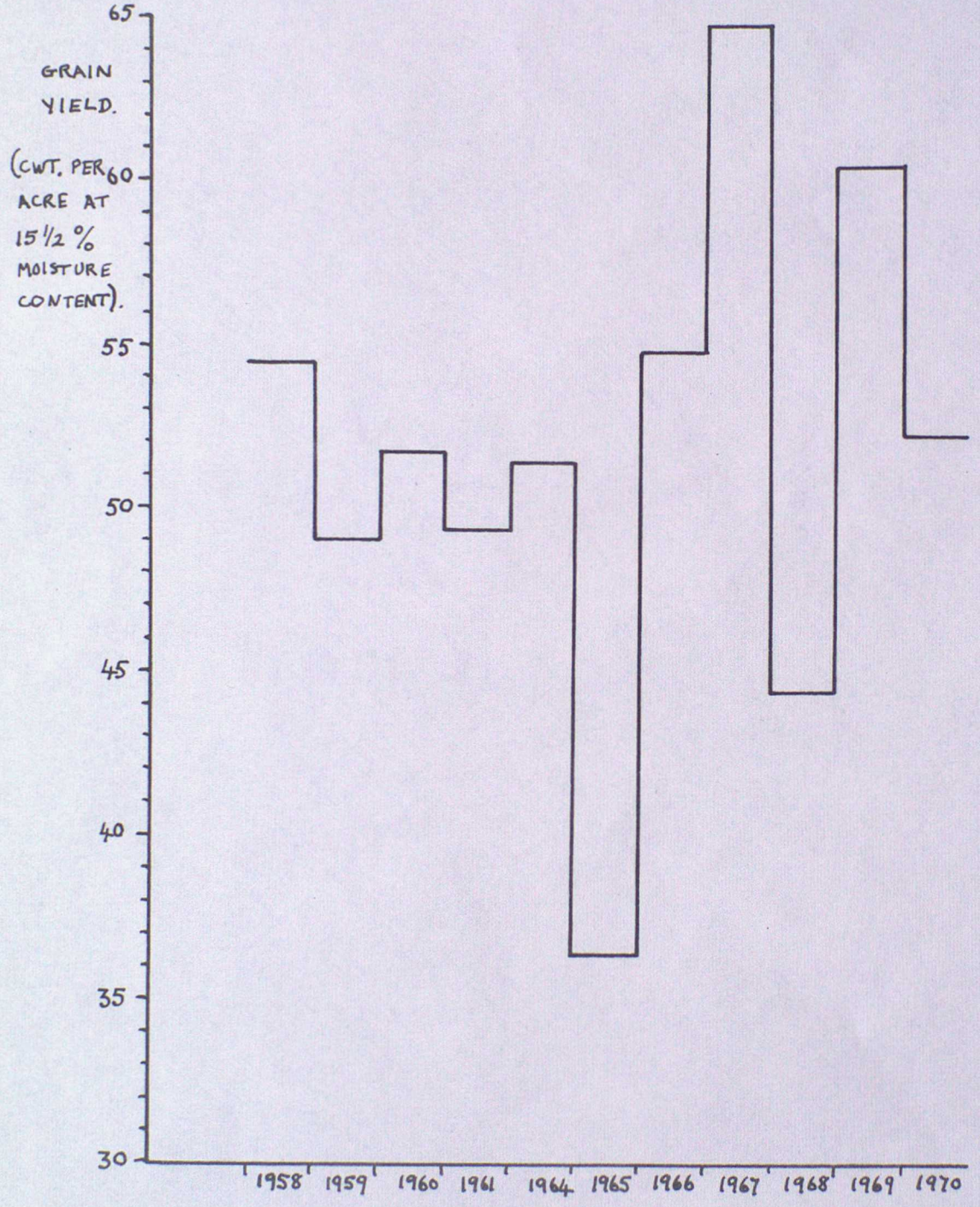
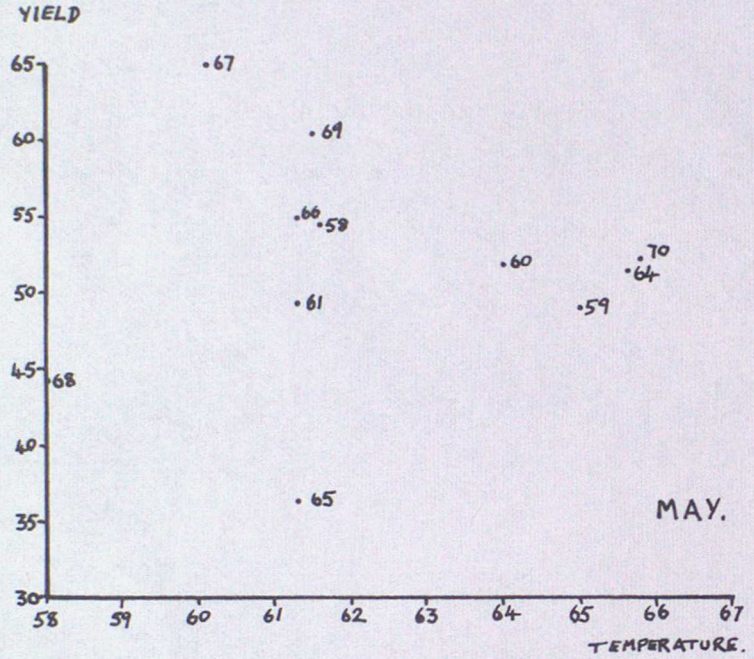
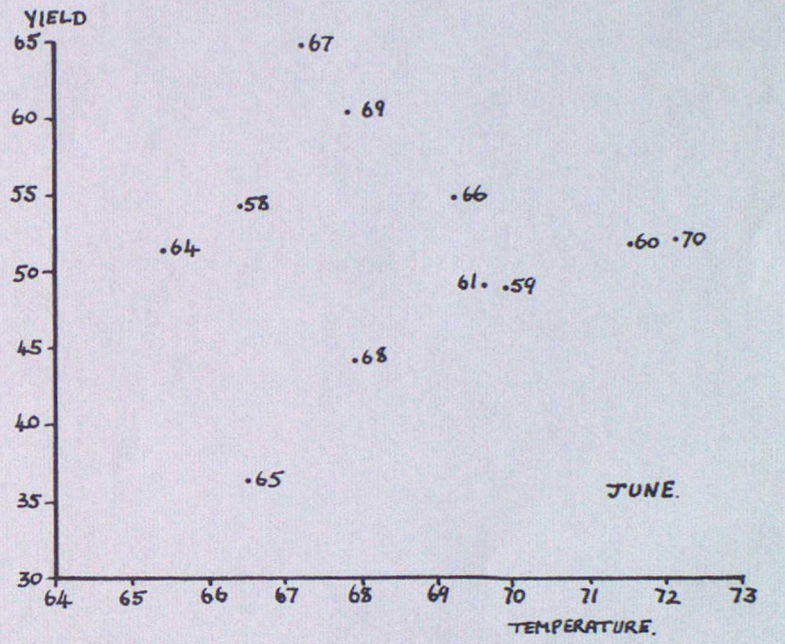


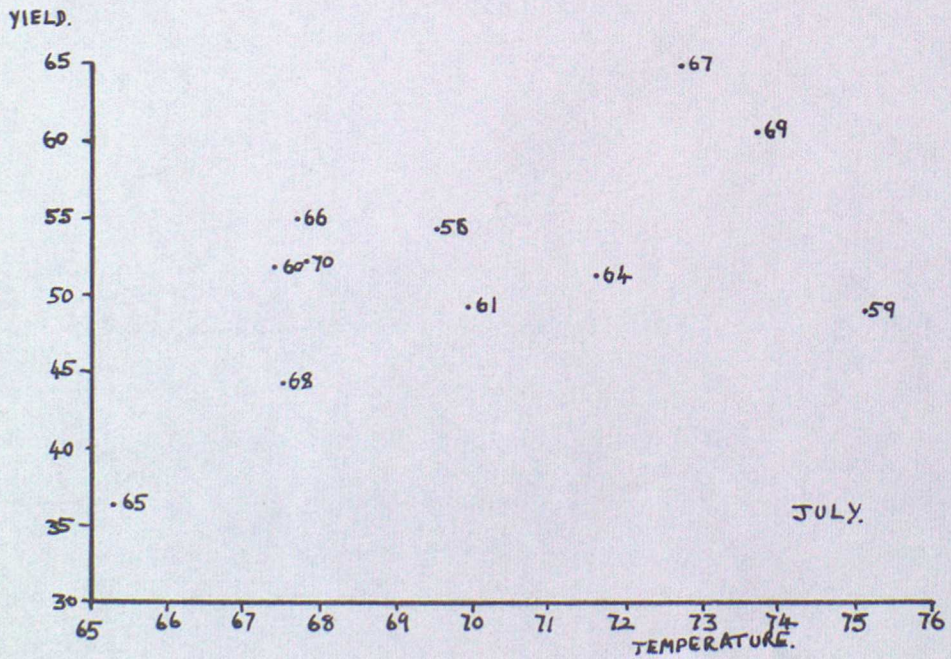
FIGURE 1.

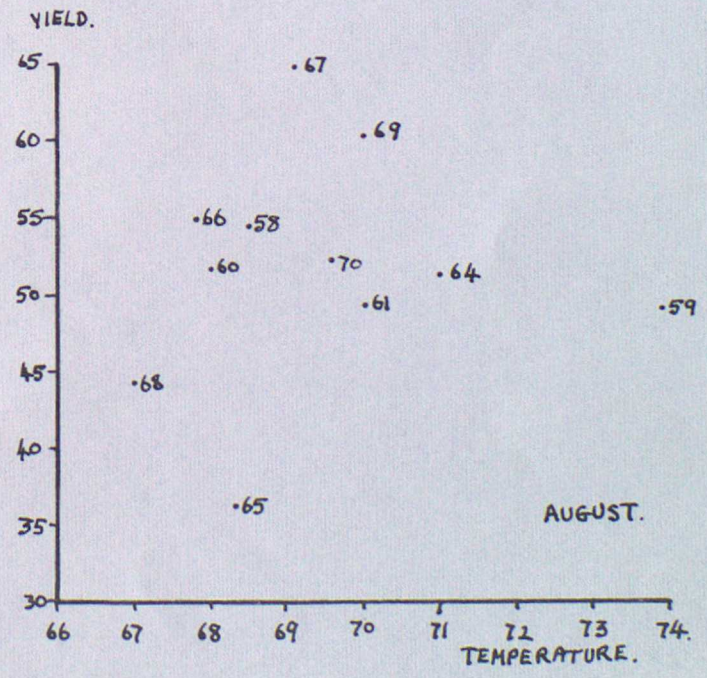
YEAR TO YEAR VARIATION IN GRAIN MAIZE YIELD AT WYTHAM.

FIGURE 2. RELATION BETWEEN GRAIN YIELD (CWT. PER ACRE AT 15 1/2 % MOISTURE CONTENT) AND THE MEAN MONTHLY MAXIMUM TEMPERATURE (°F).









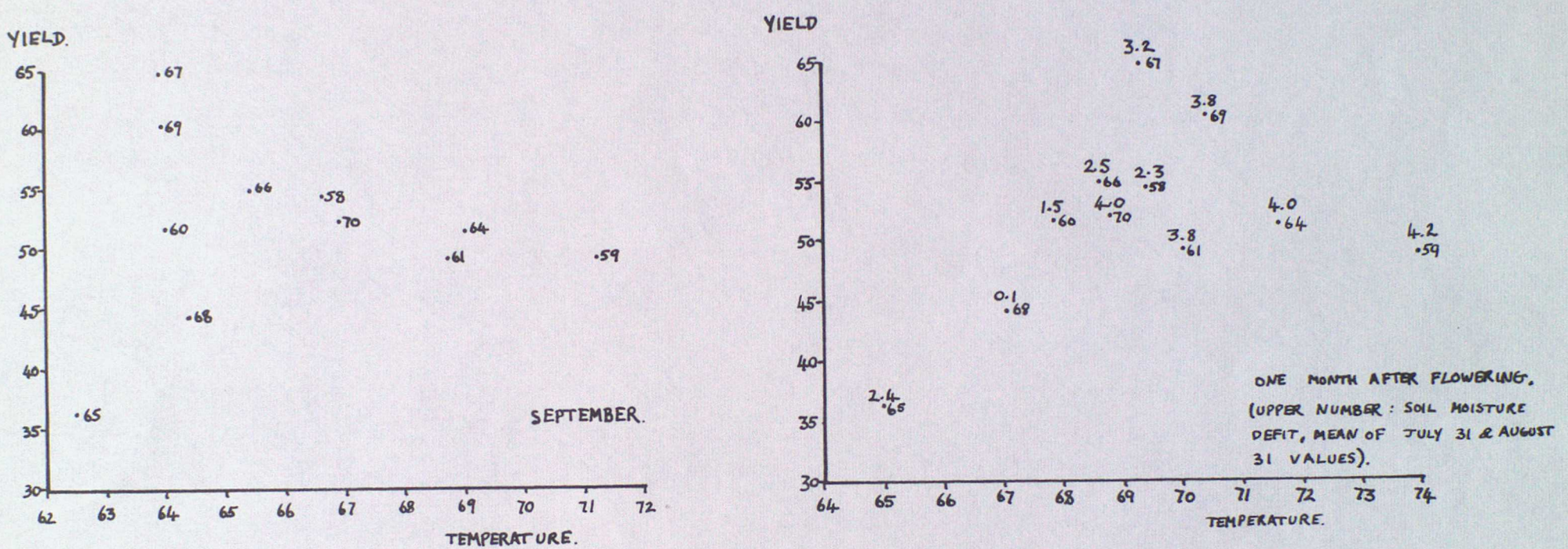
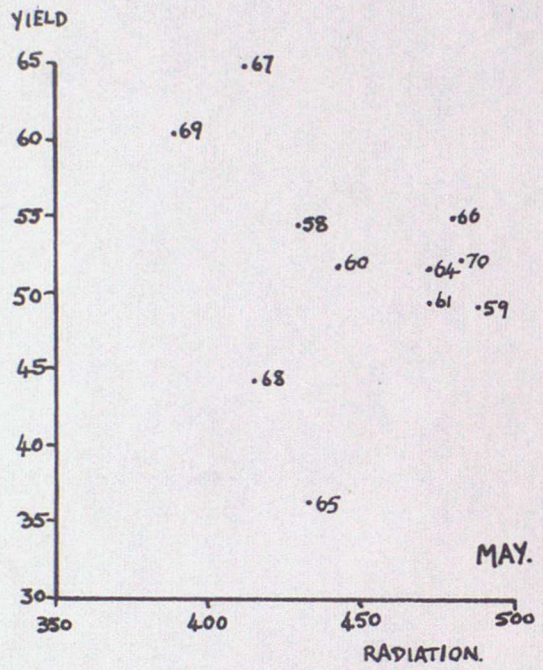
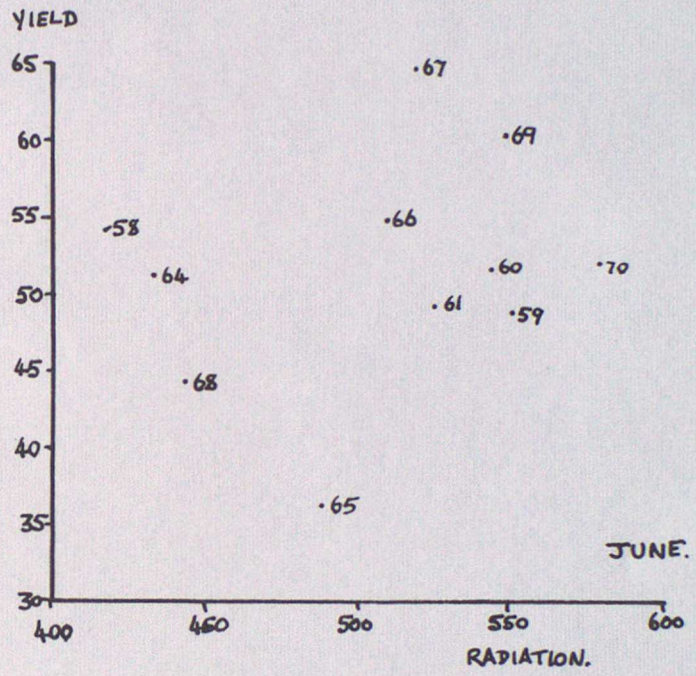
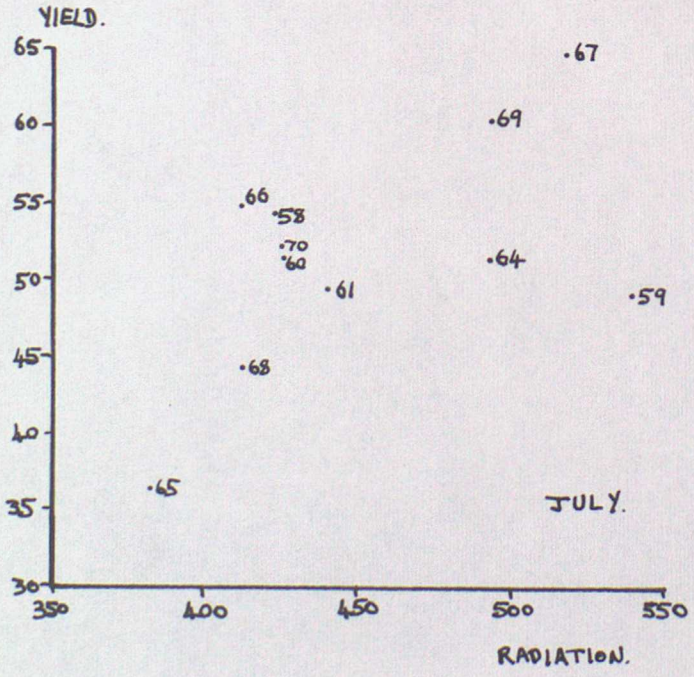


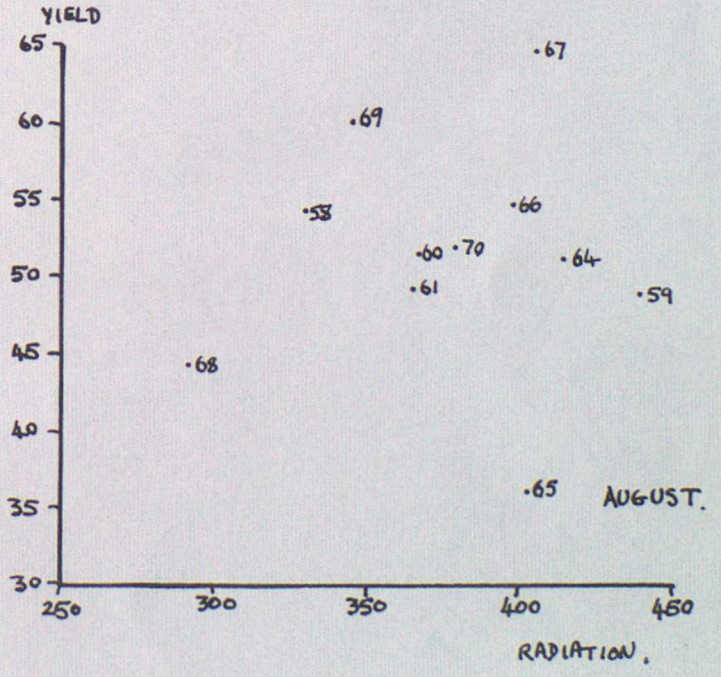
FIGURE 2. RELATION BETWEEN GRAIN YIELD (CWT. PER ACRE AT 15 1/2 % MOISTURE CONTENT) AND THE MEAN MAXIMUM °F FOR SEPTEMBER (ON THE LEFT), AND FOR ONE MONTH AFTER FLOWERING (ON RIGHT).

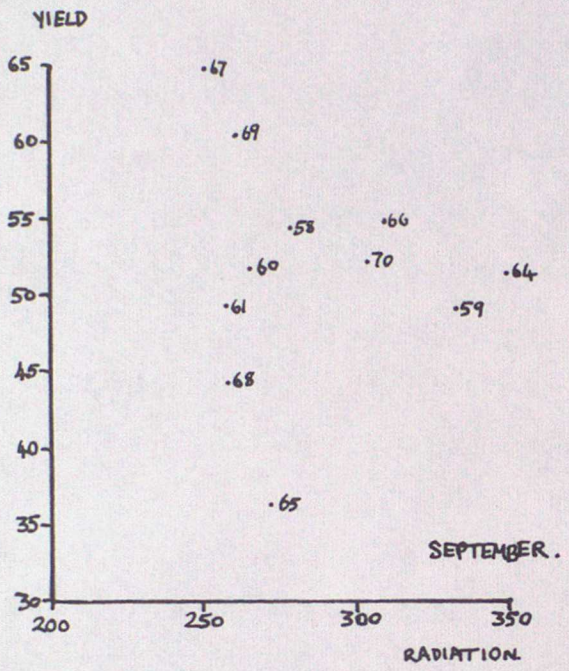
FIGURE 3 : RELATION BETWEEN YIELD (CWT. PER ACRE AT 15½ % MOISTURE CONTENT) AND RADIATION (MW. HRS. PER SQ. CM.) BY MONTHS.

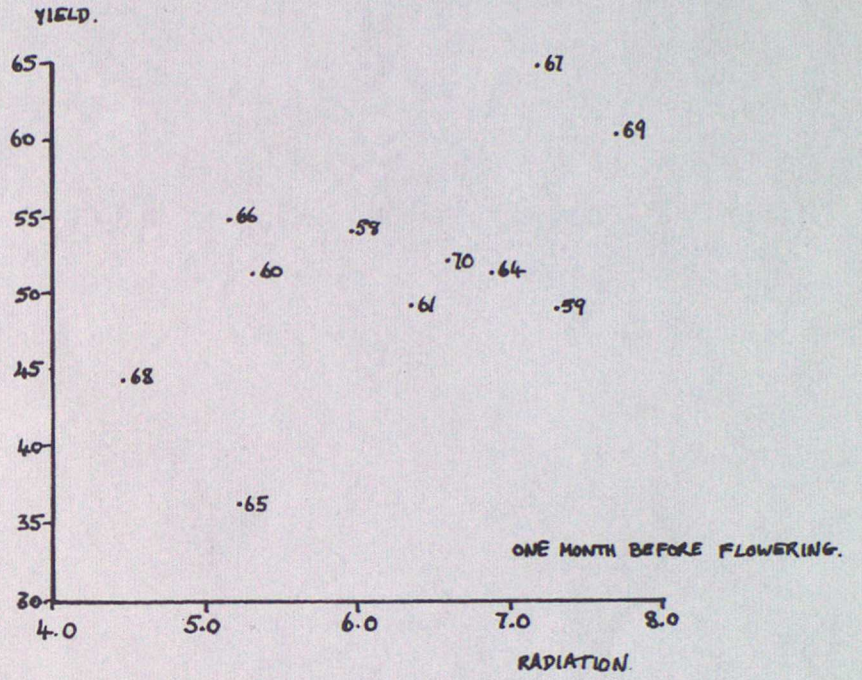












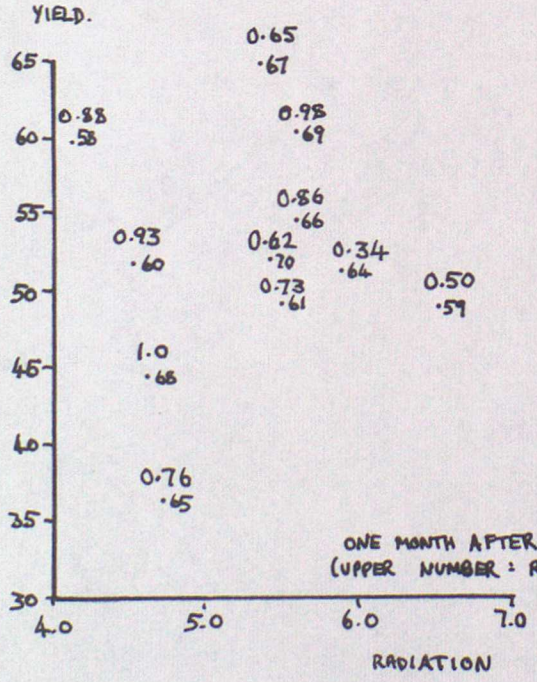


FIGURE 3: RELATION BETWEEN YIELD (CWT. PER ACRE AT 15½ % MOISTURE CONTENT) AND RADIATION (MW. HRS. PER SQ. CM. IN SEPTEMBER; MM. WATER LATENT HEAT OTHERWISE).

FIGURE 4. GRAIN YIELD AND MAY RAINFALL.

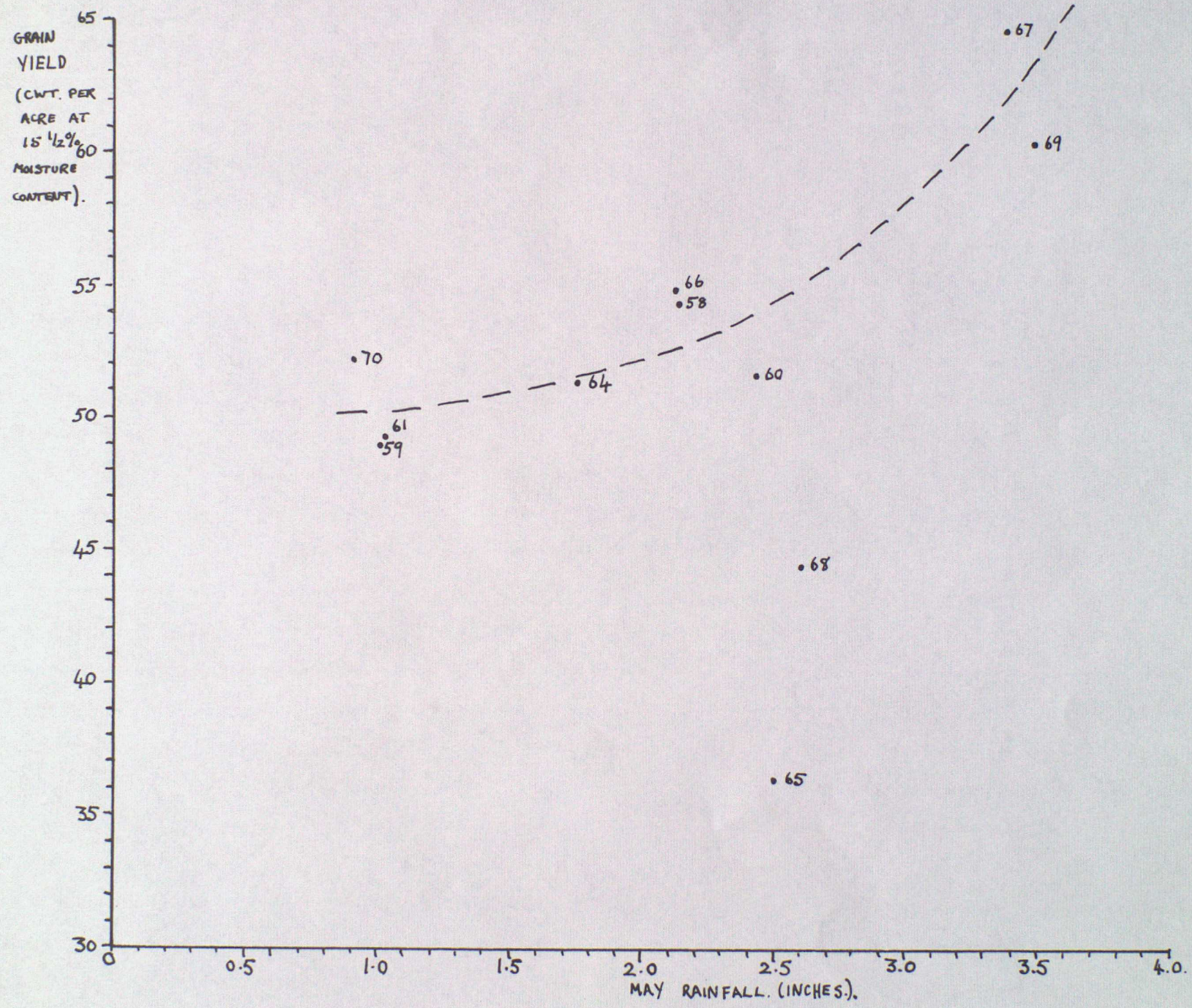
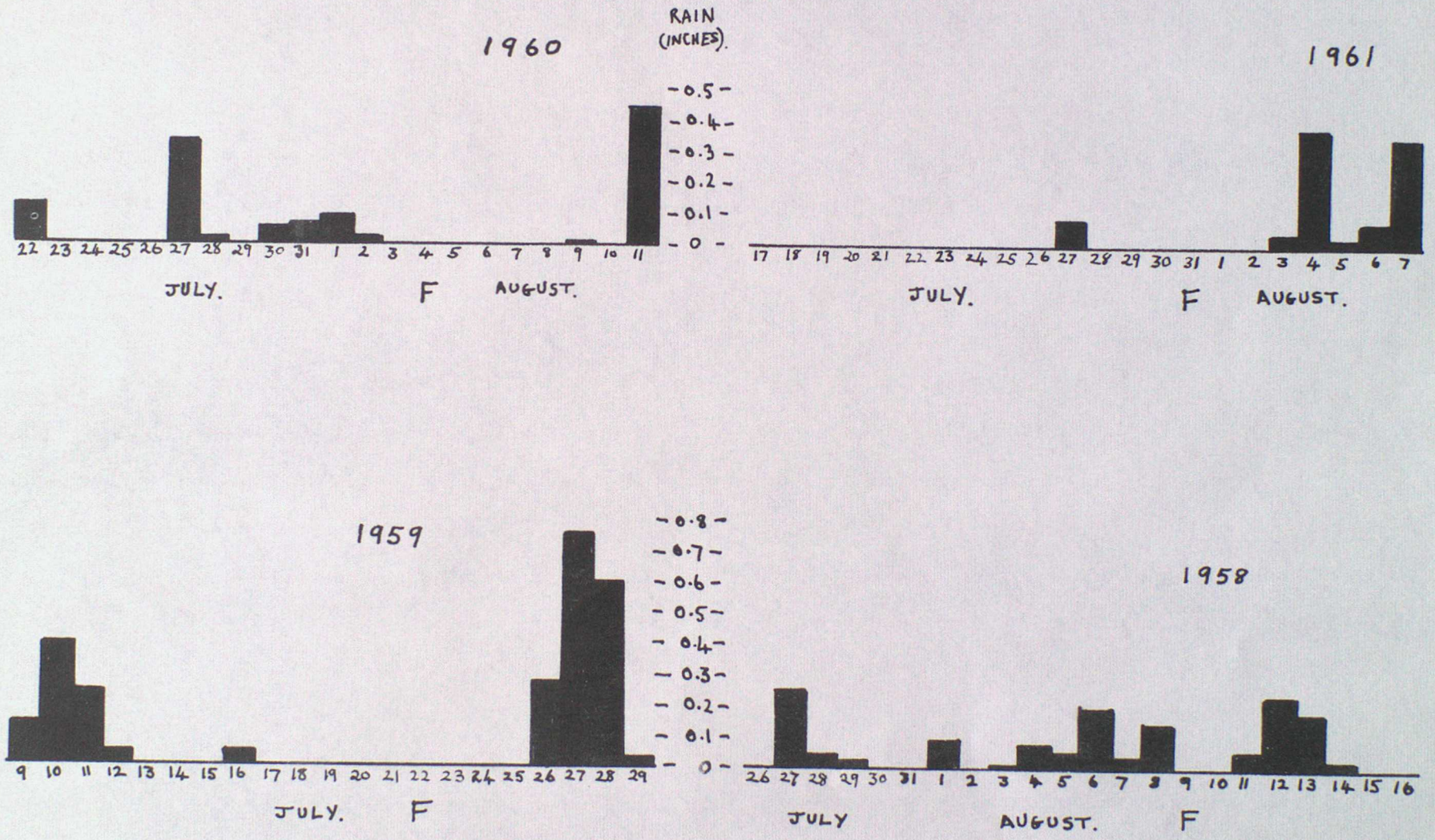


FIGURE 5.

RAINFALL PATTERNS AROUND THE FLOWERING DATE. (F).



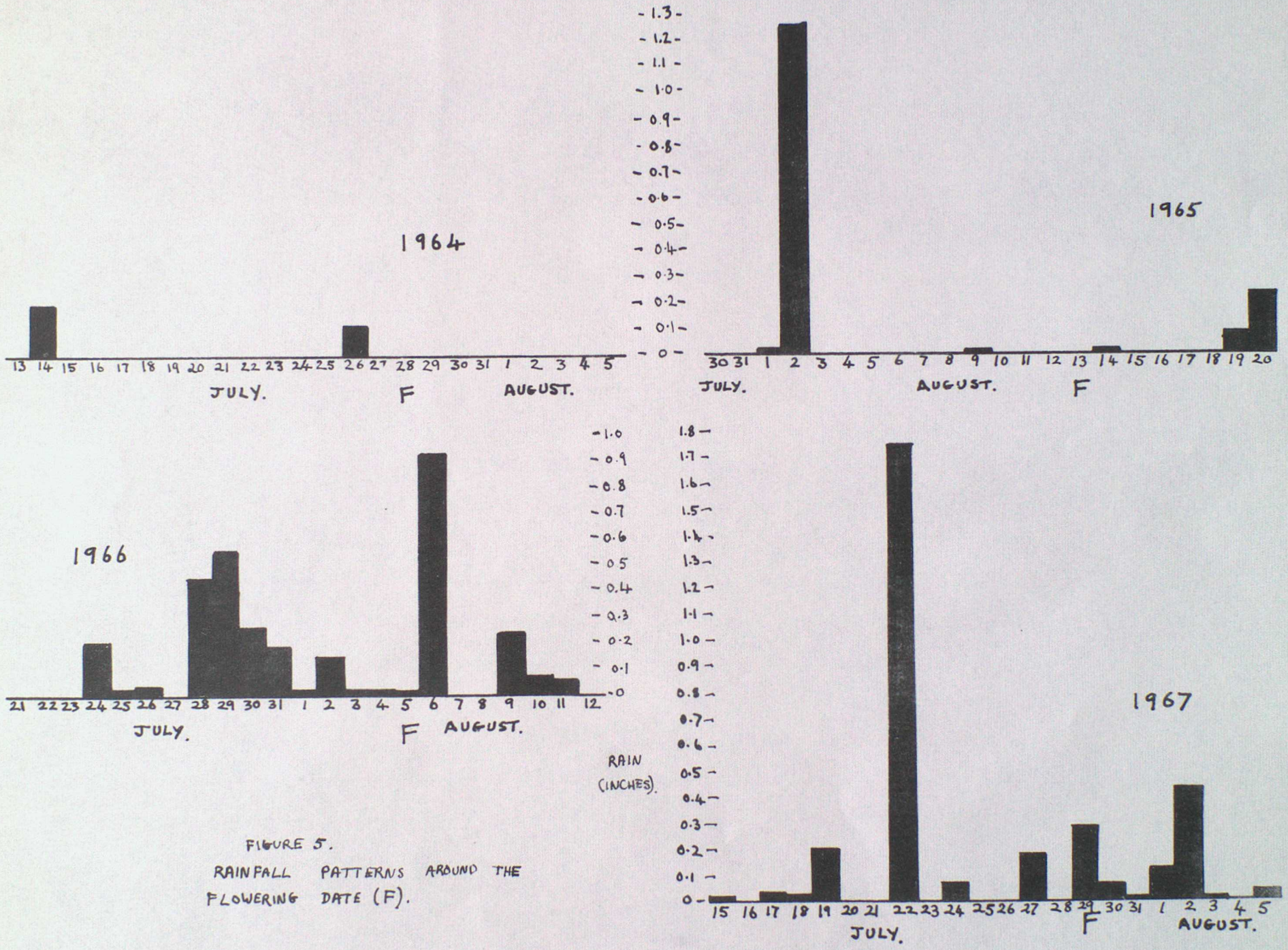
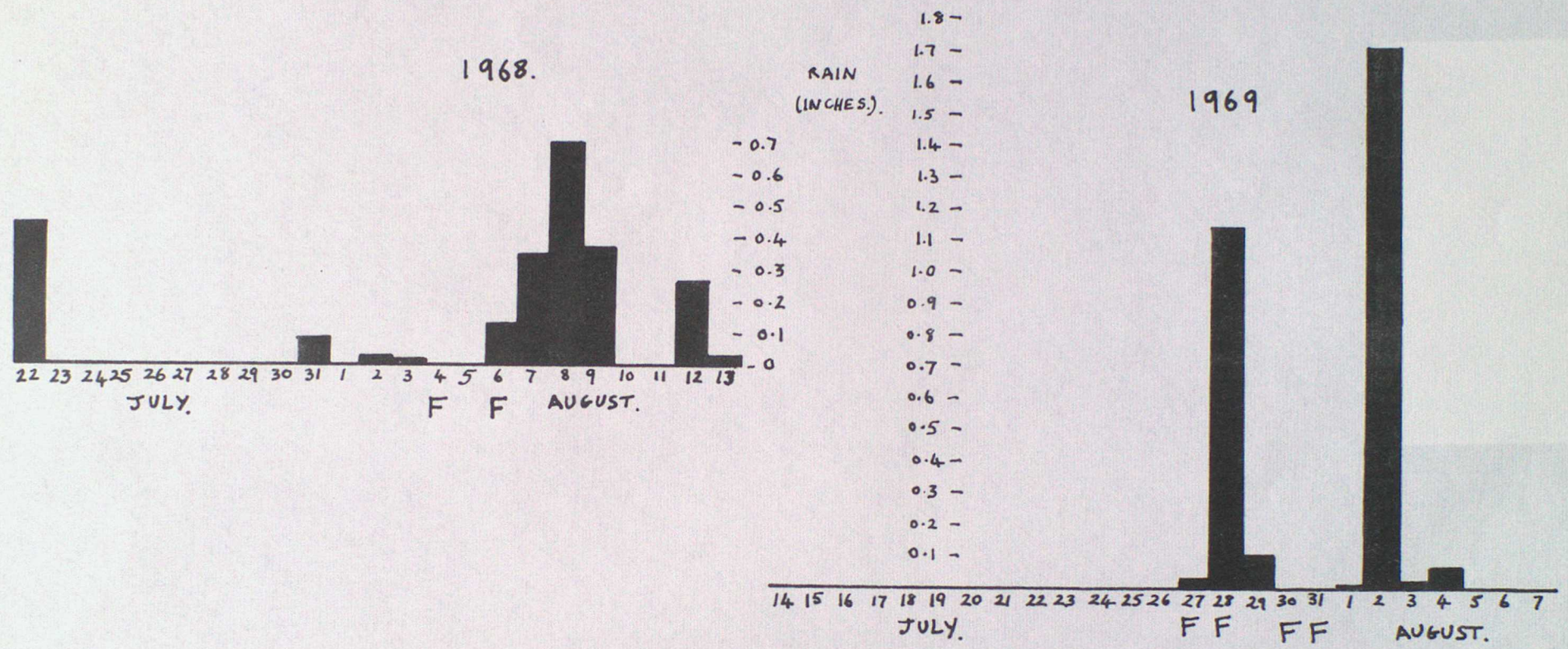
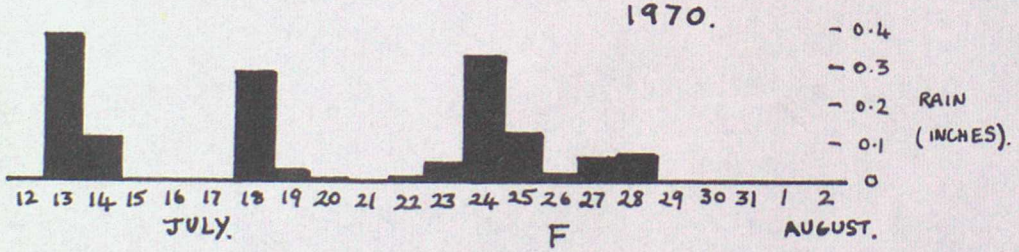


FIGURE 5.
RAINFALL PATTERNS AROUND THE FLOWERING DATE (F).





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